INDOOR AIR QUALITY ASSESSMENT

Middle School East
45 Main Street
Milford, MA 01757

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Bureau of Environmental Health Assessment
Emergency Response/Indoor Air Quality Program
September 2004

Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health (CEH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality at Middle School East (MSE), 45 Main Street, Milford, MA. The request was prompted by concerns about mold as a result of chronic roof leaks and excessively humid weather experienced during August 2003.

On March 4, 2004, a visit to conduct an indoor air quality assessment was made to this school by Cory Holmes, an Environmental Analyst in BEHA's Emergency Response/Indoor Air Quality (ER/IAQ) Program. The assessment primarily focused on mold. Mr. Holmes was accompanied by Paul Mazzuchelli, Director, Milford Board of Health, Joe Pfeil, Principal, MSE and for portions of the assessment, Robert Quinn, Facilities Director, Milford Public Schools.

The MSE is a three-story, red brick on slab building constructed in 1923, originally as a catholic high school. A wing was added in 1960. Milford Public Schools has occupied the building since the mid-1970s. With the exception the handicap access construction, no major renovations have reportedly been made to the building. The school consists of general classrooms, science classrooms, music rooms, media center, gymnasium and locker rooms, cafeteria, art rooms and office space. Windows are openable throughout the building.

Methods

BEHA staff performed a visual inspection of building materials for water damage and/or microbial growth. Moisture content of water damaged building materials was measured with a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe. Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID).

Results

The school houses approximately 340 eighth grade students and a staff of approximately 40. The tests were taken during normal operations at the school. Test results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were above 800 parts per million (ppm) in 12 of 28 areas, indicating inadequate ventilation in some areas surveyed. Fresh air in classrooms of both the original wing and 1960 addition is mechanically supplied by a unit ventilator (univent) system (Figure 1). Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building (Picture 1) and return air through an air intake located at the base of each unit. Fresh and return air are mixed, filtered, heated and provided to classrooms through an air diffuser located in the top of the unit. Univents were found deactivated in a number of classrooms. Obstructions to airflow, such as items on top of univents, and tables and desks in front of univent returns were also seen in a number of classrooms. To function as designed, univents must be activated and allowed to operate. Importantly, univent air diffusers and univent returns must remain free of obstructions.

The original building has no means of mechanical exhaust ventilation, but relies on a natural gravity system (Picture 2). Mechanical exhaust ventilation in the 1960 wing is provided by rooftop motors and ducted to classroom vents (Pictures 3 and 4). A number of these vents were found obstructed by various items in several classrooms (Picture 4). Without sufficient supply and exhaust ventilation, environmental pollutants can build up, leading to indoor air quality complaints. As with univents, exhaust vents must remain free of obstructions.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of occupancy. In order to have proper ventilation with a mechanical ventilation system, the systems must be balanced subsequent to installation to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that HVAC systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last systems balancing was not available at the time of the assessment.

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens, a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, see Appendix A.

Temperature measurements ranged from 69^{o} F to 80^{o} F, which were outside the BEHA recommended comfort range in several areas (Table 1). The BEHA recommends that indoor air temperatures be maintained in a range of 70^{o} F to 78^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Building occupants expressed a variety of temperature control/comfort complaints. Heat complaints were noted in classroom 24, specifically from the univents. Complaints were also noted from occupants in the computer classrooms, 71A and 71B. Classroom 71, originally used as a general classroom, was subdivided and is now used as two computer rooms. Consequently, the room division also separated the ventilation system components, leaving room 71B without exhaust ventilation. The combination of limited air exchange in these areas and the excess heat generated from computers and related equipment can lead to temperature and/or indoor air quality complaints.

The relative humidity measured in the building ranged from 30 to 56 percent, which was below the BEHA recommended comfort range in some areas. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

In the experience of BEHA staff, excessively humid weather can provide enough airborne water vapor to create adequate conditions for mold growth in buildings. Relative humidity in excess of 70 percent can provide an environment for mold and fungal growth (ASHRAE, 1989). In general, materials that are prone to mold growth can become colonized when moistened for more than 24 to 48 hours. Since hot, humid weather persisted in Massachusetts for more than 14 days during the month of August (The Weather Underground, 2003), materials in many schools and buildings were moistened for an extended period of time.

Prior to the BEHA assessment, roof repairs were made and water damaged ceiling tile systems were replaced in a number of classrooms. BEHA staff examined conditions above the ceiling plenum and found no visible water damage, mold growth or associated odors. Moisture content was measured in water damaged classroom ceiling tiles that were not replaced. No elevated moisture content was detected in these tiles.

Elevated moisture content was detected in wall plaster in the library (Picture 5). A roof leak in the corner of the library was reportedly repaired recently. At the time of the assessment, BEHA staff recommended drying this area with fans and heat. The US Environmental Protection Agency (US EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

School officials reported that thirty-six areas on the roof were patched during the summer of 2003. Additional repairs were made during February 2004 vacation. However, the building continues to have active roof leaks, most notably in the gymnasium. School officials reported that the MSE is scheduled for a roof replacement over the summer of 2004.

Clogged sinks with standing water were noted in science classroom 202 (Picture 6). If sinks do not drain properly, standing water can become stagnant and provide a source of mold growth and odors.

Plants were observed in several classrooms. Plants, soil and drip pans can serve as sources of mold growth. Plants should be properly maintained, over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants in one classroom were located on top of paper towels (Picture 7). Paper towels are a porous material that can provide a medium for mold growth, especially if wetted repeatedly. Plants should also be located away from ventilation sources to prevent aerosolization of dirt, pollen or mold.

Other Concerns

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address airborne pollutants and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions of reduce carbon monoxide levels (MDPH, 1997).

ASHRAE adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter. As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

Carbon monoxide should not be present in a typical, indoor environment. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. Outdoor carbon monoxide concentrations were non-detectable or ND (Table 1). Carbon monoxide levels measured inside the school were also ND.

As mentioned, the US EPA also established NAAQS for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter (μg/m^3) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, the US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standards requires outdoor air particle levels be maintained below 65 μg/m^3 over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment. Outdoor PM2.5 concentrations were measured at 66 μg/m^3 at the time of the assessment (Table 1). In most cases, PM2.5 levels measured in the school reflect outdoor levels (Table 1). Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors.

Of particular note is the technical education classroom, room 25, which had an elevated PM2.5 reading of 827 $\mu g/m^3$. Wood dust and debris were observed on flat surfaces throughout the room (Picture 8). This second floor classroom contained a number of wood cutting machines that were operating during the assessment. This classroom did not have general exhaust ventilation to remove naturally occurring pollutants. In addition, the room lacked a local exhaust system dedicated to collecting dust from equipment.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC concentrations were also ND (Table 1).

Please note, that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While no TVOC levels measured exceeded background levels, materials containing VOCs were present in the school. A container of paint thinner was observed on the floor next to an empty flammable storage locker (Picture 9). In addition to containing potentially irritating VOCs, paint thinner is a highly flammable material. Several classrooms contained dry erase boards and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain VOCs, such as methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve (Sanford, 1999), which can be irritating to the eyes, nose and throat.

In an effort to reduce noise from sliding chairs, tennis balls had been spliced open and placed on chair legs (Picture 10). Tennis balls are made of a number of materials that are a source of respiratory irritants. Constant wearing of tennis balls can produce fibers and off-gas VOCs. Tennis balls are made with a natural rubber latex bladder, which becomes abraded when used as a chair leg pad. Use of tennis balls in this manner may introduce latex dust into the school environment. Some individuals are highly allergic to latex (e.g., spina bifida patients) (SBAA, 2001). It is recommended that the use of materials containing latex be limited in buildings to reduce the likelihood of symptoms in sensitive individuals (NIOSH, 1997). A question and answer sheet concerning latex allergy is attached as Appendix B (NIOSH, 1998).

The copy room contained two photocopiers. VOCs and ozone can be produced by photocopiers, particularly if the equipment is older and in frequent use. Ozone is a respiratory irritant (Schmidt Etkin, 1992). No local exhaust ventilation was installed in this area to help reduce excess heat and odors.

Several other conditions that can affect indoor air quality were noted during the assessment. Several rooms had missing and/or dislodged ceiling tiles (Picture 11). Missing and/or dislodged ceiling tiles can provide a pathway for the movement of drafts, dusts and particulate matter between rooms and floors. Accumulated chalk dust was noted in some classrooms (Picture 12). Chalk dust is a fine particulate that can easily become aerosolized, irritating eyes and the respiratory system.

Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made:

1. Examine each univent for function. Survey classrooms for univent function to ascertain if an adequate air supply exists for each room. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the calibration of univent fresh air control dampers.
2. Operate all ventilation systems that are operable throughout the building (e.g., gym, auditorium, classrooms) continuously during periods of school occupancy and independent of thermostat control. To increase airflow in classrooms, set univent controls to "high".
3. Inspect exhaust motors and belts for proper function. Repair and replace as necessary.
4. Consider installing motorized fans on existing (gravity feed) ductwork to provide mechanical exhaust ventilation. This is of particular importance in room 25. Consideration of a local exhaust system dedicated to collecting equipment dust should also be given to the technical education classroom. If not feasible, consider discontinuing use of wood cutting machinery in classroom 25.
5. Remove all blockages from univents and exhaust vents to ensure adequate airflow.
6. Install a passive vent in the door to computer room 71-B to provide air exchange.
7. Consider adopting a balancing schedule of every 5 years for mechanical ventilation systems, as recommended by ventilation industrial standards (SMACNA, 1994).

8. Consider installing a portable air-conditioning unit in the computer rooms (71 A & B) to control temperature.
9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Drinking water during the day can help ease some symptoms associated with a dry environment (e.g., throat and sinus irritations).
10. Continue with plans for roof replacement. Ensure leaks are repaired and replace water damaged ceiling tiles and wall plaster. Examine the area above and around these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial.
11. Unclog drains in science area. If necessary, contact a licensed plumbing contractor to make repairs.
12. Consult "Mold Remediation in Schools and Commercial Buildings" published by the US EPA (2001) for further information on mold. Copies of this document can be downloaded from the US EPA website at: http://www.epa.gov/iaq/molds/mold_remediation.html.
13. Clean chalkboards and dry erase board trays regularly to avoid the build-up of particulates.
14. Replace missing/dislodged ceiling tiles.
15. Consider providing local exhaust ventilation for photocopiers in the copy room.
16. Ensure flammable products are stored in the proper cabinets.
17. Consider discontinuing the use of tennis balls on chairs to prevent latex dust generation.

18. Consider adopting the US EPA (2000b) document, "Tools for Schools" in order to maintain a good indoor air quality environment on the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.

19. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. These materials are located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

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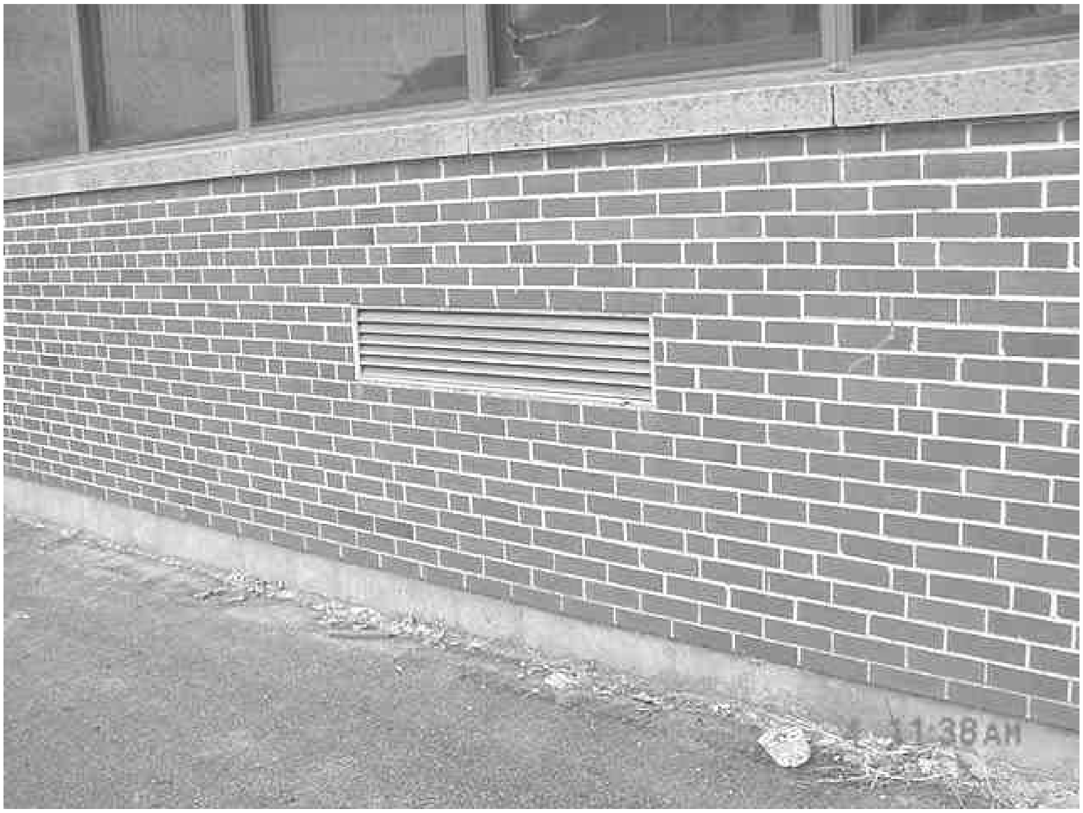
Picture 1



Univent Fresh Air Intake

Picture 2

Natural Gravity Feed Vents on Roof of Original Building

Picture 3

Mechanical Exhaust Fans on Roof of the 1960 Wing

Picture 4

Classroom Exhaust Vent Obstructed by File Cabinet

Picture 5

Water Damaged Wall Plaster in Library

Picture 6

Clogged Sink With Standing Water in Science Room

Picture 7

Plants on top of Paper Towels

Picture 8

Unvented Wood Cutting Machines and Debris in Classroom 25

Picture 9

Container of Paint Thinner on Floor Next to Flammable Cabinet

Picture 10

Tennis Balls on Chair Legs in Classroom

Picture 11

Missing Ceiling Tiles

Picture 12

Accumulated Chalk Dust in Classroom

East Middle School **Indoor Air Results**

45 Main Street, Milford, MA **March 3, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background (outdoors)	56	44	405	ND	ND	66		-	-	-	Cloudy, light rain, moderate traffic
202	71	40	1489	ND	ND	49	23	Y	Y	Y	Exhaust vent backdrafting, UV deactivated, sinks clogged-standing water
201	71	33	776	ND	ND	40	0	Y	Y	Y	UV and exhaust vent obstructed by furniture
203	72	37	1230	ND	ND	43	19	Y	Y	Y	UV obstructed by items, DO
Gym	73	32	490	ND	ND	38	0	N	Y	Y	Active roof leaks-contractor notified for repair, DO
101	72	30	507	ND	ND	38	0	N	Y	Y	UV-deactivated, DO, 18 CT
Cafeteria	73	39	1400	ND	ND	45	300	Y	Y	Y	DO, 2 of 4 UV-on, Vent hood in kitchen serves as exhaust for cafeteria

ppm = parts per million parts of air
µg/m3 = microgram per cubic meter

AD = air deodorizer
AP = air purifier

CD = chalk dust
DEM = dry erase marker
DO = door open
ND = non detect
PC = photocopier

PF = personal fan
TB = tennis balls
UF = upholstered furniture
UV = univent

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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74	74	35	948	ND	ND	41	12	Y	Y	Y	
Life Skills	72	31	473	ND	ND	39	0	Y	Y	N	DO, TB
71 A	71	34	610	ND	ND	43	2	Y	Y	Y	20 + computers and related equipment, no AC
71 B	73	33	615	ND	ND	38	2	N	Y	N	Reccommend passive vent in door for exhaust ventilation, 20 + computers and related equipment, DEM
Art Room	74	32	1500	ND	ND	54	12	N	Y	N	UV off, paint thinner on floor next to flam storage cab, flam cab empty, door open to art room, 11 CT
Tech Ed	72	38	1419	ND	ND	827	13	Y	Y	N	DO, wood working machines operating, no local exhaust ventilation, no general classroom exhaust ventilation, WD plaster-flashing, TB

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									Supply	Exhaust	
22	71	31	504	ND	ND	38	1	Y	Y	Y	No draw exhaust vent, 5 CT
20	79	35	1054	ND	ND	52	23			Y	DO, plants
6	69	31	494	ND	ND	49	0	Y	Y	Y	
Music Room	73	36	990	ND	ND	40	28	Y	Y		DO
Copy Room									Y	N	2 photocopiers no local exhaust
Speech & Language	72	44	612	ND	ND	40	0		Y	Y	Exhaust ventilation no draw
10	72	31	566	ND	ND	40	19	Y	Y	Y	Plants near UV, DO, chalk dust, 2 CT

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Nurse	73	31	644	ND	ND	39	1	Y	N	N	DO, 2 CT
Rest Room Boys Basement									Y	Y	Exhaust off
Social Studies	74	34	995	ND	ND	41	22	Y	Y	Y	UV obstructed by items, chalk dust, DEM
24	80	36	1130	ND	ND	40	9	Y	Y	Y	DO, heat complaints, chalk dust, DEM
Library	72	30	552	ND	ND	37	2	Y	Y		Elevated moisture readings-wall plaster, peeling paint and WD, roof drain-fixed, DO, plants
French	72	31	797	ND	ND	37	1	Y	Y	Y	Plants on paper towels, UV deactivated, 16 occupants gone 15 min, chalk dust, plants, DO
104	69	56	775	ND	ND	49	13	Y	Y	Y	DO, DEM

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									Supply	Exhaust	
102	70	49	789	ND	ND	44	8	Y	Y	Y	UV deactivated, DO, DEM
100	71	47	1028	ND	ND	46	14		Y	Y	DO, low moisture content CTs
72	70	35	609	ND	ND	38	0	Y	Y	Y	UV off, DEM
21	75	34	970	ND	ND	47	11	Y	Y	Y	UV obstructed by furniture and other items, chalk dust

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